8.9 GEOLOGY, SOILS, AND SEISMICITY

8.9.1 Affected Environment

Physiography

PTA is in the Humuʻula Saddle between the two major peaks on the island of Hawaiʻi; Mauna Kea lies to the northeast, and Mauna Loa lies to the south. The cantonment area, which is adjacent to Saddle Road that traverses the northeast corner of PTA, is at an elevation of 6,400 feet msl (1,950.7 meters). The slope of the Mauna Kea volcano rises steeply (about a 26 percent slope) from Saddle Road to an elevation of 13,796 feet msl (4,207 meters) over a distance of about 6 miles (14.5 kilometers). The slope of Mauna Loa, by contrast, rises to the southwest at about a 4 percent slope to an elevation of 13,678 feet msl (4,169 meters) over a distance of about 20 miles (32.2 kilometers). To the west of these two peaks is the Hualālai volcano (about 8,690 feet msl, 2,650 meters). Elevations within PTA range from 4,030 to 8,650 feet msl (1,228 to 2,637 meters).

The military vehicle trail from Kawaihae Harbor to PTA runs south inland of Highway 270 and rises to an elevation of about 250 feet (76.2 meters) near the junction with Highway 19. The trail continues east, paralleling Highway 19 along the foot of the Kohala Mountains to the western edge of Waimea (Kamuela). This segment rises to an elevation of about 2,500 feet (762 meters) over a distance of about 10 miles (16.1 kilometers). Near Waiʻaka, on the outskirts of Waimea, the trail turns south and runs west of Highway 190 approximately following the 2,400-foot (731.5-meter) elevation contour until the junction with Saddle Road (Route 200). The trail crosses Highway 190 west of a small volcanic cone called Nahonaoahe and continues upslope, roughly parallel to Saddle Road, until it reaches PTA at a point near the Puʻu Keʻekeʻe cinder cone.

Geology

Figure 8-22 is a geologic map of the northern portion of the island of Hawaiʻi, showing the locations of PTA and PTA Trail. PTA is on the saddle between the Mauna Loa and Mauna Kea volcanoes. Most of PTA is on lava flow deposits erupted from Mauna Loa, the largest active volcano in the world. Lava from Mauna Loa's last eruption, in 1984, covered 16 square miles (41.4 square kilometers) of land in three weeks. The lava erupted from the Northeast Rift Zone, which extends northeast from the Mauna Loa crater and skirts the southeast boundary of PTA. The lava flowed within 4 miles (6 kilometers) of Hilo (USGS 1997).

PTA is underlain by overlapping basalt flows erupted from Mauna Loa and Mauna Kea. The three most recent flows responsible for the surface deposits at PTA are Hāmākua flows from Mauna Kea that occurred during the Pleistocene, Laupāhoehoe flows from Mauna Kea that occurred during the Holocene, and Kaʻū flows from Mauna Loa that have occurred as recently as 1935 (USARHAW and 25th ID[L] 2001b). The more recent flows have not entered the PTA boundary.

Figure 8-22
Geologic Map of Pōhakuloa Training Area

The lower half of the WPAA is within the Waimea Plains, which were formed by lava flows from Mauna Kea that butted up against the older Kohala Mountains. The Kohala Mountains are now covered with a blanket of volcanic ash soils. The lava is predominantly pāhoehoe and ‘a‘ā basalt flows, scoria (cinder), and ash deposits of the Hāmākua Volcanics Series (Wolfe and Morris 1996). Hawaiian basalts have a high iron content, and the composition of many basalts is over 40 percent iron-containing minerals (Wolfe and Morris 1996). In some cases, the high iron content makes it difficult to discriminate ordnance from rock, and weathered basalt cobbles can look similar to oxidized ordnance (Earth Tech 2002). The parcel is dotted with cinder cones associated with the Mauna Kea volcano. The cinder cones are deposited on the upper layer of the Hāmākua Volcanic Series, which is covered by a layer of up to about 3 feet (0.9 meter) of Pahala ash erupted about 39,000 years ago.

The term “Pahala Ash” has been widely used to describe nearly all the thick soils on Hawai‘i, although it technically refers to ashes erupted from Mauna Loa or Kīluea that were deposited mainly on the southern flanks of the island. Ash deposits along the Hāmākua coast are mainly from older explosive eruptions of Mauna Kea.

Soils

Pōhakuloa Training Area

Soils are thin and poorly developed on PTA. Recent lava flows cover about 80 percent of the land surface. The low precipitation, rapid runoff, and high altitude reduce the rate of weathering, and the high slope and wind tend to prevent soils from accumulating.

Figure 8-23 shows the soil types within PTA. About 88,000 acres of PTA are classified by the US NRCS as lava flows, of which about half are ‘a‘ā flows and half are pāhoehoe flows. An additional 1,400 acres (567 hectares) are classified as cinder land. About 12,500 acres (5,062 hectares) are classified as either rock land or very stony land. The remaining approximately 10,000 acres (4,050 hectares), almost all of which is along the northern boundary of PTA near Saddle Road within training areas 1 through 17 and 22, are classified as soils formed on volcanic deposits.

The predominant soil is Keekee loamy sand on 0 to 6 percent slopes, which accounts for nearly 7,500 acres. This is a mildly to strongly alkaline soil consisting of stratified sand developed in alluvium from volcanic ash and cinders. Permeability is rapid, and runoff is slow. The hazard of wind erosion is moderate to severe. Similar sandy soils developed on slightly steeper slopes are found in the same general vicinity, including Huikau extremely stony loamy sand on 12 to 20 percent slopes, and Kilohana loamy fine sand on 12 to 20 percent slopes.

Training Area 22 contains two areas covering about 1,000 acres (405 hectares) underlain by Kekake extremely rocky muck on 6 to 20 percent slopes. These soils are described as well-drained thin organic soils overlying pāhoehoe lava. The soils are strongly acidic and have rapid permeability, but the underlying pāhoehoe lava has low permeability. These soils appear to be associated with a Mauna Loa lava flow that occurred in 1859.

Figure 8-23
Soils Map Pōhakuloa Training Area

West PTA Acquisition Area

The WPAA is underlain primarily by very fine sandy loam soils developed on volcanic ash deposits. The soils belong to the Puu Pa-Pakini-Waiaha soil association (USDA 1973). The predominant soils are Waikaloa very find sandy loam and Puu Pa extremely stony very fine sandy loam on the lower two-thirds of the parcel, and Kilohana loamy fine sand and very stony land on the upper third of the parcel.

Shallow gulches dissect the parcel; the largest of these are Waiki‘i Gulch and ‘Auwaiakeakua Gulch. The soft, permeable soils form thicker deposits in some areas. The Puu Pa soils contain a calcium carbonate cemented layer in some areas that impedes percolation of water. Although there are no perennial streams, rainfall keeps the subsoils moist along the gulches. There are areas of peat soil, where rapid cycles of vegetation growth and a moist, temperate environment have caused organic material to accumulate. The Waikaloa and Puu Pa soils are easily eroded by wind and water.

Kawaihae to PTA Trail

Figure 8-24 shows the soils along PTA Trail. From Kawaihae Harbor to about midway to Waimea, PTA follows the route of an existing military vehicle trail. The Kawaihae Harbor area is built on imported fill and is paved over. The foot of the slope just east of Kawaihae Harbor is composed of Kawaihae very rocky very fine sandy loam (KOC). The trail continues upslope over Kawaihae extremely stony very fine sandy loam on slopes of 6 to 12 percent (KNC). Kawaihae soils are moderately deep, somewhat excessively drained soils that formed in material weathered from volcanic ash. The soils have a very weak structure and are very friable (crumble easily). The soil occurs at elevations up to 1,500 feet (457.2 meters) on the leeward side of Hawai‘i, where rainfall is 5 to 20 inches (12.7 to 50.8 centimeters). These soils are used mainly for grazing.

About three miles (five kilometers) from Kawaihae Harbor, and just east of Kemole Falls, the trail turns south from the highway and approximately follows the 1,200-foot (366-meter) elevation contour. The route crosses the former Lalamilo Firing Range, just downslope of a rock wall, following the western boundary of the Pu‘u Pā Military Maneuver Area (Earth Tech 2002). The underlying soil on this traverse is still the Kawaihae extremely stony very fine sandy loam.

About 4 miles (6 kilometers) south of the highway, near Kamakoa Gulch and about 1 mile (1.6 kilometers) northeast of Waikoloa, the trail turns nearly straight upslope in the direction of the Saddle Road Junction, continuing along the southern boundary of the Pu‘u Pā Maneuver Area, and rising about 800 feet (244 meters) in 3 miles (5 kilometers). A road from here crosses the rock wall and ends at a water tank and two wells. The lower portion of this upslope segment is underlain by Kawaihae extremely stony very fine sandy loam, which lines the gulch. Just beyond the water tank, the road crosses the gulch and continues on very stony land (rVS) from an elevation of about 1,400 feet (427 meters) to about 1,600 feet (488 meters).

Figure 8-24
Soils Map PTA Trail

At about the 1,600-foot (488-meter) elevation contour, the trail crosses about 1 mile (2 kilometers) of Puu Pa extremely stony very fine sandy loam on 6 to 20 percent slopes (PVD). Like the Kawaihae soils, Puu Pa soils are moderately deep, well-drained soils that formed in material weathered from volcanic ash, have a weak structure, and are very friable. They are distinguished from Kawaihae soils mainly by occurrence at elevations between 1,000 to 2,500 feet (305 to meters), where slopes range from 6 to 100 percent and annual rainfall is 20 to 35 inches (51 to 89 centimeters). Permeability is moderately rapid, and runoff is medium. The soils are used mainly for pasture. At an elevation of about 1,900 feet (579 meters), the trail turns abruptly south again for about 4 miles (6 kilometers), following an existing unpaved track for about 2 miles (3 kilometers), and then continues above the 1,800-foot (549-meter) contour, where there is no existing track, until it intercepts a paved road. The trail continues upslope along the paved road for a distance of about 4 miles (6 kilometers), alongside ʻAuwaiakeakua Gulch, to the ʻAuwaiakeakua Water Tank at Highway 190.

The soil along about the last 7 miles (11 kilometers) of this segment is mainly Waikaloa very fine sandy loam on 6 to 12 percent slopes (WLC). The Waikaloa soil is interspersed with Puu Pa and Kamakoa very fine sandy loam on 6 to 12 percent slopes (KGC). Waikaloa soils are deep to very deep, well-drained soils that formed in basic volcanic ash. Slopes range from 2 to 20 percent. The mean annual rainfall is about 15 inches (38 centimeters). The soil has weak structure throughout the profile and is friable. Depth to bedrock is greater than 5 feet (1.5 meters). A strongly cemented layer containing calcium carbonate occurs in most locations at a depth of about 4 feet (1 meters)

Highway 190 marks the western boundary of the WPAA. The rest of the route, through the WPAA, is generally straight up the slope. The route passes over approximately equal amounts of Waikaloa and Puu Pa soils, encountering a short segment underlain by Kaimu extremely stony peat on 7 to 25 percent slopes (rKED). The Kaimu soil occurs south of Popoo Gulch and east of Keʻāmuku, at an elevation of between 3,200 and 3,400 feet (975 and 1,036 meters). The Kaimu soil is moderately deep, somewhat excessively drained, and highly organic. This soil formed in organic material mixed with minor amounts of basic volcanic ash in ʻaʻā lava. The soil occurs in areas where the mean annual rainfall is about 35 inches (89 centimeters).

About 3 miles (5 kilometers) downslope from the 1010 Parcel, at an elevation of about 4,300 feet (1,311 meters), the trail encounters Kilohana loamy fine sand on 12 to 20 percent slopes (KZD), interspersed with very stony land. The Kilohana soil is deep, somewhat excessively drained, and forms in material weathered from volcanic ash. Kilohana soils are on uplands, generally at elevations of 5,000 to 6,500 feet (1,524 to 1,981 meters) with slopes of 12 to 20 percent. Mean annual rainfall is about 30 inches (76.2 centimeters), and depth to bedrock is more than 6 feet (2 meters). The soils are very highly permeable and runoff is slow. Outcrops of ʻaʻā lava flows are common. In the 100 Parcel, the trail intercepts Keʻekeʻe Road, an unpaved road that runs along the northwest side of Puʻu Keʻekeʻe cinder cone, where the soils are classified as cinder land.

Chemical Constituents in Soils at Pōhakuloa Training Area

The US Army Corps of Engineers, Sacramento District, conducted a surface soil and surface water investigation at PTA from November 12 to November 14, 2002. Objectives were to get a snapshot of current conditions on ranges at PTA in order to predict the potential for exposure to munitions constituents on the planned range areas for this EIS. A total of 46 soil samples were collected from Range 5 (the Grenade Range), Range 9 (the Engineering Demolition Range), Range 10 (temporary impact area), Range 11 (impact area), various firing points (firing points 309, 311, 420, 802, and 804), and Range Control (considered to be an ambient background site). No surface water was observed, so no water samples were collected. A summary report of the investigation is included in Appendix M-1. The results are summarized and briefly discussed below.

As with the investigation conducted at SBMR (See Section 5.9), the data from the investigation of surface soils at PTA are intended to support the description of current conditions and to provide evidence of the effects of past training activities on surface soils and surface water. The investigation was not intended to be a comprehensive study of the distribution of contaminants on the ranges.

Figure M1-2 in Appendix M1 shows the locations of the sample points (some points are not labeled, but the locations are close to other labeled points from the same range). Thirty-two of the sample locations were near Training Area 21, either in the impact area just west of there or at firing points or just downrange from firing points near the western edge of the area. Eight samples were collected at firing points FP309 and FP311 in Training Area 8. Four samples were from firing point FP420 in Training Area 12, next to Saddle Road. Two samples were from near the Range Control office in the cantonment area.

Semi-volatile Organics. As discussed in Section 5.9 for samples collected at SBMR, metals, explosives, and several semi-volatile organic compounds (phthalate esters and polynuclear aromatic hydrocarbons) were detected. The phthalate esters are plasticizers and are ubiquitous in the environment. They may have been present because of plastic parts in munitions. PAHs are also common in the environment at low concentrations. They are a product of combustion of heavy organic compounds, including wood, oils, and tars. None of the semi-volatile organics exceeded industrial soil PRGs, although benzo (a) pyrene was detected in one sample from the Range 9 Demo Area at 0.190 mg/kg, which is close to the industrial soil PRG of 0.211 mg/kg.

Explosives. The sampling detected six explosives included 2,4,6-TNT (TNT); 2,4-DNT (a degradation product of TNT); RDX, HMX, nitroglycerin, and perchlorate. With the exception of 2,4-DNT and perchlorate, these are the same compounds that were detected in samples from SBMR.

Four of the 46 samples had detectable concentrations of TNT, ranging from 0.8 to 1.5 mg/kg. None exceeded the industrial soil PRG of 57 mg/kg. The detections were in three samples from the Range 9 Demo Area and in one sample from Range 5. Three samples contained 2,4-DNT, at concentrations ranging from 0.18 to 2.0 mg/kg. The industrial soil PRG for 2,4-DNT is 1,200 mg/kg. Perchlorate was detected in one sample, from firing point

FP309 in the northwest corner of Training Area 8. The concentration was below the industrial soil PRG. Of these six explosives, five samples of RDX exceeded its industrial PRG of 15.6 mg/kg.

Metals. As discussed in Section 5.9, metals occur naturally in soils, and Hawaiian soils are no exception. However, human activities may also contribute to the background levels of metals in soils. Even in natural conditions, metals concentrations are expected to vary. One reason for different concentrations of metals in soils from different areas of PTA is that different lavas may have different compositions and concentrations of metals. Soils at PTA are relatively thin, poorly developed, and have not had much time to be mixed or redeposited. Therefore, the metals concentrations in soils developed on different flows of different ages may vary. Frequency distribution plots can be used to help identify the normal ranges of metals in soils and to identify unusually high concentrations. The high concentrations may be from natural sources, too, but if the concentrations are very different from the "typical" range of concentrations, then it is more likely that the metals are from human sources.

Among the metals that were analyzed for in the samples, the most abundant metals in basalt minerals are aluminum, barium, chromium, iron, nickel, and zinc. Other metals would generally be expected to be present at lower concentrations. Except for iron, none of these metals were detected at concentrations above the industrial soil PRGs. Chromium, nickel, and zinc were detected in one sample from Range 11 at much higher concentrations than in the other samples but still less than the industrial soil PRGs. Iron did not exceed the industrial PRG in any samples. Zinc showed a clustered distribution in the range of 100 to 200 mg/kg, with a few much higher detections. The highest detected concentrations were in samples from Range 5 and Range 11.

Looking at other, less abundant metals, most were detected at concentrations below their respective industrial soil PRGs. The highest concentrations were generally detected in a single sample from Range 11 (R11TANK-01), or in samples from Ranges 9 or 10. Exceptions to this were beryllium and selenium, higher concentrations of which seem to be randomly distributed. In fact, the highest concentrations of these seemed to be in the "background" samples from near the Range Control office.

The highest lead concentrations were detected in samples from Ranges 9, 10, and 11. Two samples (one from Range 10, and sample R11TANK-01) contained concentrations above the industrial soil PRG.

Based on these results, it appears that both elevated metals concentrations and detectable explosives concentrations were generally found in the impact areas of Ranges 5, 9, 10, and 11. Few of the concentrations exceeded industrial soil PRGs.

The combined noncancer occupational health risk associated with exposure to the observed metals concentrations from the soil investigation is 0.9, or just below the threshold of 1 for no further action. Excluding the calculated values for iron, aluminum, and manganese, i.e., known naturally occurring metals, the combined risk would be 0.29, which mainly results from lead. The combined carcinogenic risk from metals is 7.0×10^{-6}. This is above the one in one million cancer risk threshold, but within the range of 10^{-4} to 10^{-6}, which is considered acceptable under some circumstances.

Volcanism, Seismicity, and other Geologic Hazards

As shown in Figure 8-25, areas with slopes greater than 30 percent are primarily limited to the slopes of Mauna Kea, north of Saddle Road, and to the southern portion of PTA, on the north-facing slope of Mauna Loa.

Volcanic Eruption Hazards

The USGS has divided the island of Hawaiʻi into Lava Hazard Zones based on the probability of coverage by lava flows. Other hazards from volcanic eruptions are not classified in this system. Zone 1 has the highest risk and Zone 9 has the lowest. PTA overlies areas categorized as zones 2, 3, and 8 (County of Hawaiʻi 2002a). Zone 2 includes areas in which 15 to 25 percent of the land area has been covered by flows since 1800; the eastern margin and northeastern corner of PTA are in Zone 2. Zone 3 has had 1 to 15 percent coverage by lava flows since 1800; most of PTA is in Zone 3. Zone 8 has had no lava coverage over the past 750 years, and only a few percent of the area was covered in the past 10,000 years. Zone 8 represents areas near or north of Saddle Road that are underlain by lava erupted from Mauna Kea. PTA Trail is entirely within Zone 8.

Infrequently, Hawaiian volcanoes erupt explosively. In 1790, Kīlauea erupted explosively, creating a surge of hot gases and fine dust that killed a group of Hawaiian warriors and their families near the summit.

Another hazard of Hawaiian volcanoes is emission of sulfur dioxide gas and other toxic constituents. The gas forms a strong acid, hydrogen sulfide, when it reacts with moisture in the atmosphere or in peoples' lungs. The particulates and gases form a mixture called "vog," meaning volcanic smog, that can range from a dispersed atmospheric haze resembling smog to a ground-hugging cloud resembling fog (USGS 2000a).

Earthquake Hazards

The island of Hawaiʻi is the locus of most of the earthquake activity that occurs in the Hawaiian Islands. A magnitude 7.2 earthquake in 1975 that originated beneath Kīlauea was the largest earthquake to originate in Hawaiʻi during the past century. Hazards associated with earthquakes include ground shaking, liquefaction, landslides, and tsunamis. The 1975 earthquake generated a tsunami that killed two people and damaged property along the coast (USGS 1997).

The USGS has prepared maps showing the horizontal ground acceleration in firm rock, as a percentage of the acceleration of gravity, for a given probability of exceedance within a given number of years. Acceleration is the rate of change in speed or direction of an object, and it is what makes buildings come apart in a strong earthquake. A 10 percent probability of exceedance in the next 50 years means that there is a 10 percent chance that a larger event will occur in the next 50 years. PTA is in an area in which there is a 10 percent probability

Figure 8-25
Steep Slopes at Pōhakuloa Training Area

that an earthquake will cause a ground acceleration of more than 40 to 60 percent of gravity in the next 50 years, with the likely size of the earthquake increasing to the south, in the direction of Kīlauea and the south coast.

The severity of ground shaking depends on the local geologic conditions. Seismic waves may be amplified by soft sediments, for example, while wave energy tends to be transmitted efficiently through hard rock. Most of PTA is underlain by hard rock with thin or no soils, so seismic waves would not be amplified. The intensity of an earthquake is another measure of earthquake severity. Earthquake intensity is a qualitative way of comparing earthquakes on a scale of I to XII. Intensity is estimated at points where the shaking is felt, while magnitude is measured at the source of the earthquake. In August 1951, an earthquake with a magnitude of 6.9 and a maximum intensity of IX on the Modified Mercali Scale damaged structures on the Kona Coast and caused a 12-foot tsunami. The earthquake also initiated a number of destructive landslides and caused cracks in the coastal highway (USGS 2001a).

8.9.2 Environmental Consequences

Summary of Impacts

Table 8-18 summarizes the impacts of the three alternatives. Soil erosion from construction and training activities has been identified as a potentially significant and unmitigable impact.

Table 8-18
Summary of Potential Geologic Resources Impacts at PTA

Impact Issues	Proposed Action	Reduced Land Acquisition	No Action
Soil loss	⊗	⊗	⊙
Soil erosion and loss from wildland fires	⊘	⊘	⊘
Increased soil compaction	⊘	⊘	⊙
Exposure to soil contaminants	⊙	⊙	⊙
Slope failure	⊙	⊙	⊙
Volcanic and seismic activity	⊙	⊙	⊙

In cases when there would be both beneficial and adverse impacts, both are shown on this table. Mitigation measures would only apply to adverse impacts.

<u>LEGEND:</u>

⊗ = Significant
⊘ = Significant but mitigable to less than significant
⊙ = Less than significant
○ = No impact
\+ = Beneficial impact
N/A = Not applicable

Four other types of geologic impacts have been identified as potentially significant but mitigable, including soil erosion and loss from wildfires, increased soil compaction, exposure to soil contaminants, and slope failure.

The loss of other important agricultural lands through conversion to military use is considered a significant impact pending a formal determination by the NRCS. The impact is considered potentially mitigable and is discussed in the section on Land Use.

The effect of enhancing soil erosion during or because of construction of PTA Trail is not expected to be significant because the potential effects would be mitigated through the implementation of standard management practices.

Volcanic hazards, while potentially significant in this area, are not expected to be significant over the life of the project because there is a low probability that erupted lava would flow onto PTA, based on distribution of past lava flows. Also, most Hawaiian eruptions would provide some warning and adequate time for evacuation, if necessary. Seismic hazards are not expected to result in significant impacts because seismic energy is not amplified in the geologic materials beneath PTA and because new structures would be designed to resist the lateral forces expected from most earthquakes generated in the region.

Proposed Action (Preferred Alternative)

Significant Impacts

Impact 1: Soil erosion. Increased soil erosion may result from mounted and unmounted maneuver training, from construction and use of PTA Trail, and from construction (site preparation) of new facilities at PTA.

Impact 1a: Soil erosion from mounted and unmounted maneuver training in PTA. The intensity of off-road vehicle use within the current boundaries of PTA will increase with implementation of the Proposed Action. ATTACC modeling was used to estimate the effects of mounted maneuver training on land condition at PTA. The model assumed an increase in the number of MIMs, from 13,659 under existing conditions to 30,900 for the Proposed Action. ATTACC modeling assumed that about 56,661 acres (3,000 hectares), or about 50 percent of the total land area within PTA, is maneuverable, but that only about 12,000 acres (4,900 hectares) (11 percent of the total area) are being used. As shown in Figure 2-6, much of this area is located adjacent to Saddle Road. The ATTACC model distributed the total MIMs over the available land area, resulting in an average of 1.14 MIMs per maneuverable acre under existing conditions, and about 2.6 MIMs per acre under the Proposed Action. Under existing conditions, it was assumed that the MIMs result in "mild" impacts on land condition in the PTA boundaries, meaning that relatively little restoration is needed to sustain the land. This may be reasonably accurate on average, but it is not accurate when applied to specific locations. For example, the INRMP identifies denudation of vegetation, major soil erosion, and severe windblown dust problems associated with maneuver training in Range 10. ATTACC modeling found that the Proposed Action would result in degradation of land condition to a "severe" condition on average, meaning that it would be much more difficult to restore and sustain the land over the long term than under existing conditions. The threshold for "severe" was assumed to occur at about 29,000 MIMs. The impact on soils is considered to be significant because it could result in additional major soil erosion, such as described for Range 10.

Regulatory and Administrative Mitigation 1a. Mitigation options include management practices identified in the Integrated Natural Resource Management Plan for PTA (USARHAW and 25th ID[L] 2001b). The ATTACC model would be used as an interactive tool in the ITAM program, to identify and categorize the areas in which impacts to vegetation and soils occur, and to monitor and track the effects of training activities and the success of land restoration practices. The LRAM component of the ITAM program consists of strategies and resource allocation for resting and repairing training lands on a rotational basis, as well as repairing damaged training areas as the need arises. Certain areas within the boundaries of PTA are restricted for protection of plant species. Additional closure of certain areas that may be sensitive to soil erosion could be evaluated; however, depending on the amount of restricted acreage, this could result in further focusing of MIMs on a reduced number of acres and would reduce the ability to accomplish the training objectives. Current mitigation practices to reduce erosion include "paving" areas susceptible to erosion with crushed rock, and revegetation. Revegetation has not yet been proven successful at PTA, and a number of studies are being conducted to evaluate different options. Problems associated with revegetation include the potential for introduction of exotic species, difficulty in propagating and maintaining native species, difficulty of initiating vegetation cover on already damaged or depleted land, and lack of alternative training sites for rotating damaged lands out of use long enough to ensure their recovery. Due to lack of demonstrated success, the proposed mitigation cannot be assumed to reduce the impacts to less than significant levels.

Impact 1b: Soil erosion from mounted and unmounted maneuver training in the WPAA. For the WPAA, the ATTACC modeling estimated that new mounted maneuver training would result in a total of 61,894 MIMs. There is now no mounted maneuver training there. Uses that could affect soil erosion include cattle grazing, civilian vehicle traffic, cinder cone quarrying operations, and periodic burning by wildfires. Also, the parcel has been used for military maneuver training in the past (it is part of the Waikaloa Military Maneuver Area), and those past uses may have already had long-term effects on land condition, which is considered part of the baseline for this evaluation. Therefore, current conditions should not be assumed to reflect "natural" or undeveloped conditions.

The results of the ATTACC modeling for the WPAA indicate that the Proposed Action would result in degradation to a "severe" land condition. The threshold for "severe" was estimated to occur at about 50,000 MIMs, and the number of projected MIMs on the parcel would be about 24 percent more than this threshold. Based on a total maneuverable land area of 22,675 acres (9,176 hectares), the Proposed Action would result in about 2.7 MIMs per acre on WPAA.

Land condition would be reduced primarily due to damage to vegetation cover from by off-road Stryker vehicle use. When vegetation is damaged, underlying soils are exposed to erosion by wind and water. Vehicles will also directly disturb soils and create tracks. These tracks then become conduits for storm runoff. In the ATTACC modeling, it was assumed that nearly all of the land in the WPAA is maneuverable by Strykers. Therefore, the MIMs were distributed over the entire area of the parcel. In practice, however, it is likely that Strykers would follow routes that are neither over rock outcrops (which would be more difficult to traverse) nor over thick soft deposits but would follow routes that skirt the margins of outcrops where the soils are relatively thin and firm. Thus, in practice, the effective maneuverable area may be less than modeled, and the effects on land condition may be more focused than assumed in the modeling. Despite lack of perennial streams, soil erosion by water during short duration storm events could result in significant local redistribution of eroded soil. Wind erosion of exposed soil would likely result in gradual removal of soils from areas where vegetation is damaged, such as in wheel tracks. Loss of soils in areas where soils are already thin could reduce the effectiveness of reseeding efforts, and seeding may not be effective in areas compacted by vehicle wheels. Over the long term, soil erosion could alter the terrain, making it more rugged, further reducing the maneuverable area, and causing MIMs to be increasingly focused on smaller areas. Due to the projected severity of the average effects of maneuver training based on ATTACC modeling, the impact on erosion and soil loss is considered significant. Although the average MIMs per acre would be similar to those within the current PTA boundary, the Keʻāmuku Parcel is steeper and the hazard of erosion is greater than within the current PTA boundary.

Regulatory and Administrative Mitigation 1b. As described in Mitigation 1a, mitigation options include management practices identified in the INRMP for PTA (USARHAW and 25th ID[L] 2001b). As within PTA, the ATTACC model would be used as an interactive tool in the ITAM program to identify and categorize the areas in which impacts to vegetation and soils occur and to monitor and track the effects of training activities and the success of land restoration practices. Based on the results of monitoring land condition, mitigation measures may be applied selectively to specific areas, based on elevation, slope, soil type, vegetation cover, runoff, and other factors. Use of crushed rock to armor the land surface would not be practicable over the entire WPAA. Options such as closing certain areas that may be sensitive to soil erosion would be evaluated, but depending on the amount of restricted acreage, this could result in further focusing of MIMs on a reduced number of acres, resulting in increased impacts. Besides revegetation by reseeding and planting native varieties of shrubs or other ground cover, engineering controls may be used to reduce water erosion. These could include identifying areas of focused drainage and placing berms or barriers to slow or disperse the runoff, or to redirect it toward existing gulches.

Additional Mitigation 1b. No additional mitigation has been proposed.

Impact 1c: Soil erosion from construction and use of PTA Trail. Construction of PTA Trail would remove existing vegetation and disturb soils. As proposed, much of the trail would be on steep slopes and would be nearly straight up the fall line of the slope. The road would be a 24-foot wide (3-meter wide) gravel bed with 3-foot wide (1-meter wide) shoulders, for a total of 30 feet (9.14 meters) width. The road may use existing road alignments and would be paved with asphalt on slopes greater than 10 percent. In effect, nearly all uphill segments would be paved with asphalt, and traverses along elevation contours would be paved with gravel. During construction, erosion by both wind and water could occur. The largest impacts are likely to be in steep slope areas containing fine loam soils, such as Waikaloa and Puu Pa sandy silt loams. This impact is considered potentially significant. After construction, the road could affect surface drainage, both by focusing drainage collected from impermeable surfaces onto adjacent lands and by interfering with natural drainage patterns. Large runoff events could result in soil accumulation in culverts at gulch crossings, resulting in flooding and possible washouts of the roadway. Each of these could result in severe soil erosion or sedimentation on lands adjacent to the road. This is considered a potentially significant impact.

Regulatory and Administrative Mitigation 1c. Soil erosion may be reduced or prevented by implementation of standard construction practices. These include scheduling construction for periods of generally favorable weather patterns (dry season, low wind); application of water or chemical emulsions to bind soil particles and resist wind erosion; use of runoff controls to direct storm water away from unprotected areas; and completion of short segments so that final drainage and surface stabilization are accomplished as quickly as possible. Drainage systems would be designed to prevent focusing of runoff. Culverts would be designed for a reasonably low frequency runoff event.

Additional Mitigation 1c. No additional mitigation has been proposed.

Significant Impacts Mitigable to Less than Significant

Impact 2: Soil erosion and loss from wildland fires. Although wildland fires, particularly grass fires, could occur at PTA or on the adjacent WPAA, the effects on soil loss would be localized because much of the land contains shallow soil or exposed rock outcrops. Many areas with soils are somewhat protected from water erosion because they are surrounded by rock outcrops. Removing grassland vegetation by fire would temporarily expose soils to enhanced water erosion, but perhaps even more so to wind erosion. Soil erosion by water would lead to soil moving and redepositing downslope. Due to lack of continuity of stream flows, soils would probably not migrate far from their upslope origins, but wind erosion could transport soil further from its original location. Under natural conditions, wildland fires occur infrequently in Hawai‘i, partly due to lack of lightning. Thus, native plant species are not well adapted to fire. Fire and loss of soil could reduce native plant species and encourage fast-growing nonnative species that recover quickly after fires. Some of these species may be more susceptible or even dependent on fire so that the occurrence of wildland fires may help to increase the chance of future wildland fires. Under the Proposed Action, training in the WPAA may increase the potential for wildland fires because it would introduce such ignition sources as the heat of engine exhaust systems coming into contact with grasses, sparks from live and nonlive munitions, and smoking. Because of the potential for soil loss if wildland fires were to spread over a large area, this is considered a significant impact.

Regulatory and Administrative Mitigation 2. As described for other installations, prevention and suppression of wildland fires on training ranges, as described in the WFMP, Pahakuloa and O‘ahu Training Areas (USARHAW and 25th ID[L] 2000a), is expected to reduce the impacts to less than significant levels. Post fire land management and rehabilitation is addressed in the LRAM element of the ITAM program, which is discussed in the INRMP for 2002 through 2006 (USARHAW and 25th ID[L] 2000a) and at the ITAM Web site, http://www.army-itam.com.

Impact 3: Soil compaction. Soil compaction may be caused by driving vehicles off roads on compressible soil. Moist soils with a high content of fine materials (silt and clay) are most likely to compact. The Waikaloa and Waimea soils in WPAA are vulnerable to compaction because they contain a high percentage of fine materials. However, soils throughout PTA tend to have a low moisture content. Therefore, the Waikaloa and Waimea soils are likely to be moderately vulnerable to compaction except shortly after storm events. Once compacted, the soils may remain compacted for a long time. Compaction of vehicle tracks may introduce increased roughness to the ground surface, leading to increased wind and water erosion. Compaction also may affect vegetation by changing soil permeability, porosity, and water content and by affecting root penetration. Significant soil compaction is expected to occur in WPAA because this area has not been previously subjected to a high degree of vehicle use.

Regulatory and Administrative Mitigation 3. No mitigation has been identified.

Additional Mitigation 3. Potential mitigation measures for this impact which would partially mitigate for soil compaction would include avoiding sensitive areas or by operating vehicles on roads to limit the amount of surface area subject to the impacts.

Less than Significant Impacts

Exposure to chemical contaminants in soils. An important factor in evaluating risk due to exposure to contaminated is soils is the fact that munitions are fired from firing points down range and into the range impact areas. These areas are not accessible to or entered by soldiers or members of the public because of the safety explosive risk they represent. Therefore, it is unlikely that human beings, either military personnel or off-post residents, would come into contact with the constituents of these munitions in the downrange or impact area soils. The only area that presents a potential opportunity for contact with contaminated soils is in the area of the proposed BAX. The construction of the BAX will require the conversion of a portion of Training Area 12 to a training area where soldiers could be exposed to the soils. However, their exposure would be limited to training for a period of days or weeks. The level of chemical compounds present Range 12 are all below their respective PRGs. Considered together, the potential duration of exposure to the chemical concentrations on the training ranges at PTA, including Range 12, represent a low risk to personnel who them.

Exposure to chemical contaminants in soils at training area 12 could occur through several pathways, including direct contact with contaminated soils, ingestion of soils, or through inhalation of windblown dust. Exposure estimates are based on assumptions about the amount of soil that might be ingested by a person who works in an area with contaminated soils. It is a generally accepted principle of risk assessment that not all exposures result in unacceptable health risks and that there are certain thresholds of exposure below which the health risks are so low that they cannot be distinguished from background risks.

As discussed in the Affected Environment section, composite soil sampling at selected ranges within PTA revealed the presence of metals, explosives, and semi-volatile organic compounds. The observed concentrations were generally less than industrial PRGs. One explosive compound, RDX, was detected in samples from Ranges 5 and 9 at concentrations above the industrial PRG while Training Area 12 was below. The risks from multiple chemical exposures are additive, and similar calculations can be done for each of the contaminants to which people may be exposed at PTA. The risks from HMX, nitroglycerin, and TNT are very small compared to the risk from RDX, and the sum of their risks is less than 0.74×10^{-6}. The risks associated with each of the metals can be calculated similarly, and the results would be similar. The highest risks are associated with the iron and aluminum in the soil, both of which occur naturally at high concentrations.

Maneuver training conducted in the WPAA would not result in significant exposures to high explosives residues in soils, either from past or proposed activities, because the training there under the Proposed Action would involve simulated rather than live artillery fire.

Overall, the sum of the carcinogenic and non-carcinogenic risks, based on the available soil sampling data and using the PRGs to estimate risk, is less than the USEPA threshold for worker exposure. It is unlikely that troop exposures to RDX or other chemicals on the ranges would be similar to worker exposures in an industrial setting. For example, workers are assumed to ingest 100 mg of soil per day, 250 days per year for 25 years. This assumption over-estimates troop exposures, because troops are likely to be exposed only temporarily, and only for short durations. No public contact with these soils will occur. Based on the conservative analysis described above, this represents a less than significant impact.

Soil erosion from construction of new facilities. Site clearing and grading for construction of new facilities would expose soils to enhanced erosion by water or wind. This impact is expected to be less than significant because the new facilities would be constructed on relatively level land using standard erosion control practices and because the impacts would be temporary.

Slope failure. Although there are many steep slopes within PTA and the WPAA, most slopes are underlain by shallow bedrock or exposed rock outcrops, so there is little potential for slope failure.

Volcanic and seismic hazards. The discussion of impacts related to volcanic and seismic hazards can be divided into two broad types of impacts: those that may be caused by the project, and those that are the result of the project being constructed in an area in which hazards exist. The impacts discussed below are mainly of the later type, but the former is discussed briefly first.

At first glance, the use of high explosives at PTA might be thought to increase the potential for volcanic eruptions or earthquakes. In reality, there is virtually no risk that this would occur because the amount of energy released in the detonation of a high explosive munition, such as a 105mm mortar round, is very small relative to the kinetic energy released in an earthquake or the heat energy contained in the magma chamber of a volcano. Most of the energy from the detonation of a mortar at the ground surface is expended in the atmosphere or in moving loose rock or soil. Only a small percentage of the energy is transferred to the rock. (Otherwise, the explosive would not be an effective weapon.) Studies have shown that even underground testing of nuclear devices did not trigger earthquakes on existing faults, although these tests have produced ruptures in the ground surface (USGS 2002a). Thus, the use of explosives at PTA is not expected to have any effect on the frequency of volcanic eruptions or earthquakes. The discussion below focuses on the effects of implementing the

Proposed Action in the volcanic and seismic environment that exists at PTA, and the potential for hazards to personnel or structures and facilities because of this environment.

PTA is subject to periodic eruptions of lava from the Mauna Loa volcano. The risk of any particular site being inundated by a lava flow is small because flows tend to be narrow and occur relatively infrequently. If it were to occur in a developed area, however, a lava flow could potentially destroy or damage structures, roads, or other facilities; could endanger lives; and could have the potential indirect effect of causing releases of hazardous materials or explosions of munitions.

PTA lies on the edge of the northeast rift zone, which last erupted in 1984. At that time, lava flowed northeastward, in the direction of Hilo. Since lava flows by gravity, its path would be determined by the location of the vent (most likely to be within a rift zone and initially near the summit, although Mauna Loa eruptions tend to develop into flank eruptions, as the vent migrates downslope along the rift). Some isolated vents are also present on the slopes of Mauna Loa, so that the location of vents cannot be predicted. Eruptions from Mauna Loa tend to be voluminous, and the lava can move quickly (up to about 5 miles per hour [8 kilometers per hour]). Therefore, if the flow is initiated in an area upslope from PTA, it is likely that PTA would be affected and that quick evacuation would be needed. Potential hazards include hazards to human safety, loss of property, detonation of stored munitions, and loss of useable land and facilities for training.

Most Hawaiian eruptions are relatively nonexplosive and involve a steady oozing or flow of lava rather than sudden violent eruptions such as occur in eruptions of many continental volcanoes. Very infrequently, explosive eruptions occur. Such eruptions have the potential to eject extremely fast-moving gas and small particles of molten rock in a pyroclastic surge. Such eruptions are impossible to outrun and can be devastating to everything in their path. It is unlikely that such an eruption would occur on Mauna Loa, but such eruptions have occurred during historic time from Kīlauea, outside the project area. Volcanic eruptions also may involve release of toxic gases, typically sulfur dioxide, which is converted to sulfuric acid by contact with water or atmospheric moisture. Sulfuric acid is an irritant to skin, eyes, lungs, etc., and in high airborne concentrations could be life-threatening.

Earthquakes are common on the island of Hawai'i, but most earthquakes are relatively small. PTA is in an area that has about a 10 percent chance of experiencing horizontal ground acceleration greater than 40 percent of gravity in the next 50 years. The island of Hawai'i is in Zone 4 of the Uniform Building Code. Forty percent of gravity is about the upper limit for standard structural design criteria used in the Uniform Building Code. Designs to resist larger forces require additional strengthening elements, and design to withstand very large forces can be cost prohibitive.

Some earthquakes are the result of movement of molten rock (magma) deep in the earth's crust as it rises along openings in the crust. Others are the result of shifts in the crust along large fractures. In both cases, either as a result of expansion of the surface or as a result of settling, surface ruptures, cracks, or depressions may appear in the ground surface. These disruptions of the surface can create hazards by damaging roads, utility lines, and buildings.

Implementation of standard procedures and engineering practices is expected to reduce the volcanic and seismic hazards to acceptable levels, although these measures cannot eliminate the hazards. Most of the measures to address hazards involve implementing timely warning systems, appropriate planning and training, and appropriate engineering design. The proposed structures at PTA would be designed to meet all federal, state, and local building code requirements. The Hawaiian Volcano Observatory provides warnings to local officials and the public of volcanic hazard conditions. The Army prepares and implements volcanic and seismic hazard plans and training, including evacuation plans for personnel and munitions in the event of an emergency.

Reduced Land Acquisition

All of the impacts identified under the Proposed Action would also occur under Reduced Land Acquisition. The addition of the QTR2 firing range could increase the intensity of land use at PTA because other training activities, which may have more impact on soils and erosion processes than those at QTR2, would be limited to a smaller area than under the Proposed Action. However, this is not expected to occur to any significant extent because the QTR2 would use land that is already proposed for use as an anti-armor live-fire and tracking range. Therefore, the impacts on geological resources of the RLA Alternative are not expected to differ from the impacts of the Proposed Action.

No Action

Significant Impacts Mitigable to Less than Significant

Impact 1: Soil erosion. Erosion impacts are limited to limited areas within PTA, such as Range 10, where the terrain is maneuverable. Observed soil erosion, as evidenced by vegetation loss, severe dust erosion, and gully formation, has been significant in the past in some localized areas. These impacts would continue to be potentially significant in localized areas. The current mitigation measures, including placement of crushed rock over the affected land surface, the requirement to fill trenches after dig in exercises, and continued experimentation with revegetation techniques, are expected to reduce these impacts to less than significant levels over time.

Less than Significant Impacts

Soil erosion from continued use of the military vehicle trail from Kawaihae Harbor to PTA. The existing military vehicle trail would continue to be used. Without pavement or drainage improvements, dust erosion impacts would continue, as would potential impacts from erosion by surface runoff. The impacts are not considered to be significant relative to long-term soil loss or erosion because the trail occupies a relatively small amount of acreage. Use of the trail would not significantly alter the rate of erosion. The trail would continue to be maintained as needed to ensure that it remains passable.

Volcanic and seismic hazards. The impacts would be the similar to those described for the Proposed Action and are considered less than significant for the same reasons described above.

Exposure to contaminated soils. The impacts would be the similar to those described for the Proposed Action and are considered less than significant for the same reasons described above.